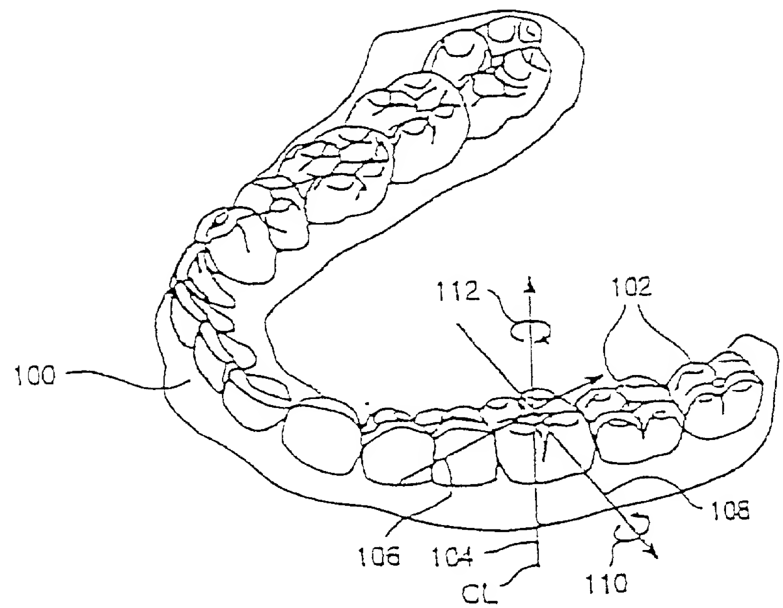

FIG. 1A

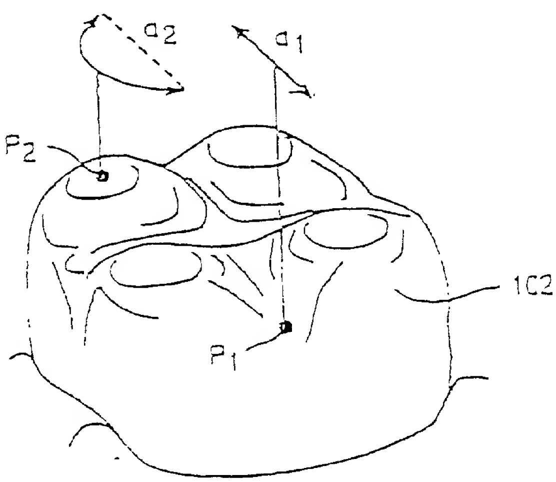

FIG. 1B

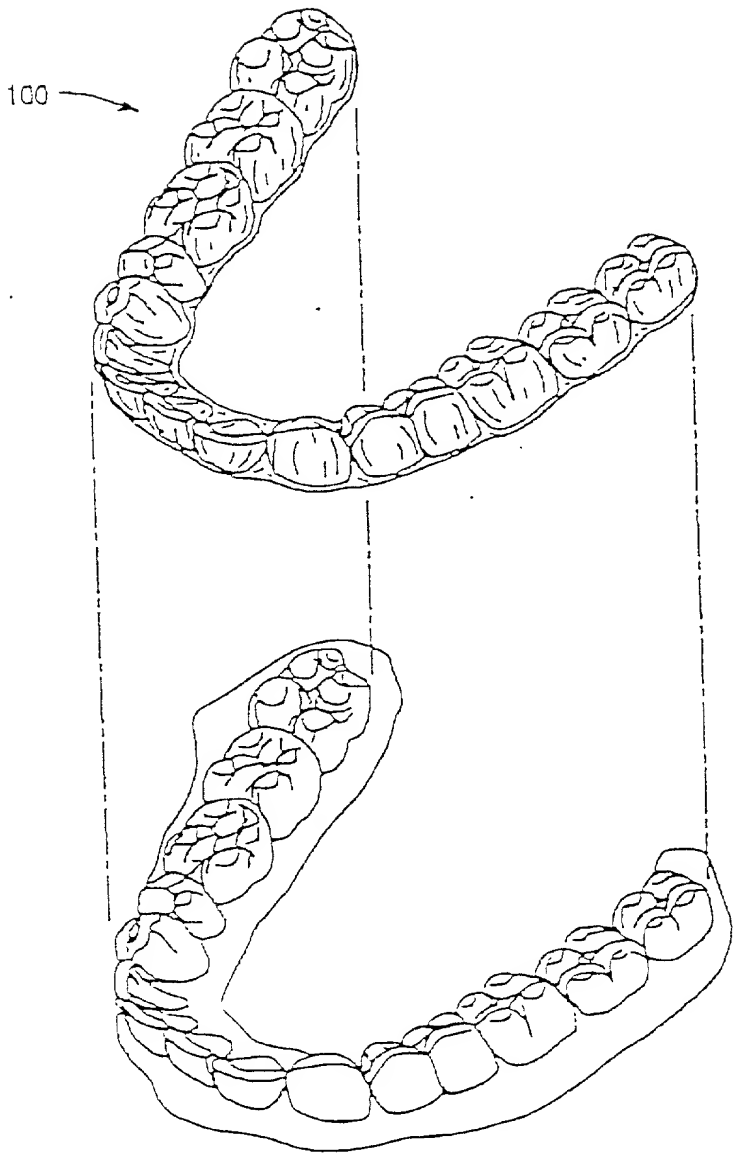

FIG. 1C

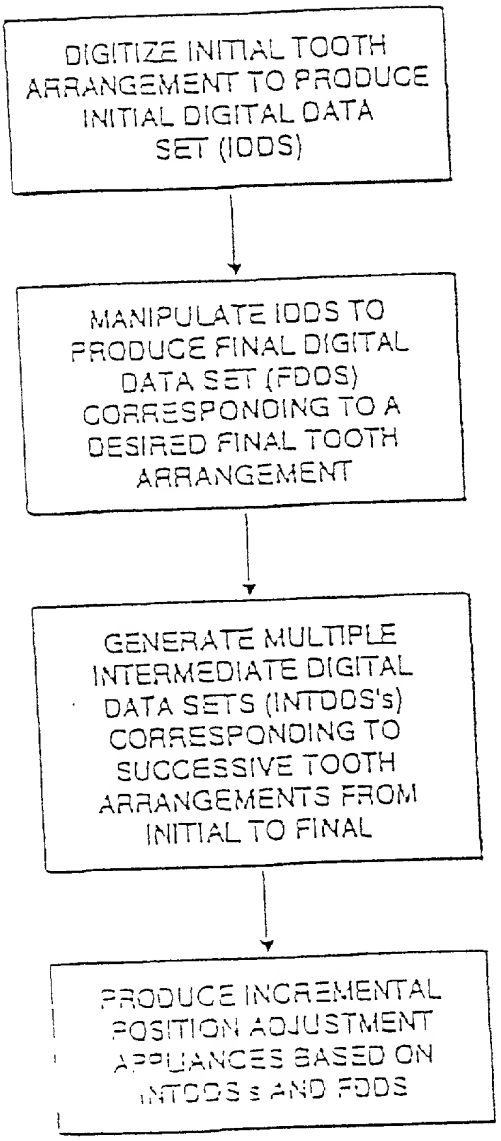
DIGITIZE INITIAL TOOTH ARRANGEMENT TO PRODUCE INITIAL DIGITAL DATA SET (IDDS)
MANIPULATE IDDS TO PRODUCE FINAL DIGITAL DATA SET (FDDS) CORRESPONDING TO A DESIRED FINAL TOOTH ARRANGEMENT
CROSS-REFERENCE FIG. 3
GENERATE MULTIPLE INTERMEDIATE DIGITAL DATA SETS (INTDDS's) CORRESPONDING TO SUCCESSIVE TOOTH ARRANGEMENTS FROM INITIAL TO FINAL
CROSS-REFERENCE FIG. 6
PRODUCE INCREMENTAL POSITION ADJUSTMENT APPLIANCES BASED ON INTDDS's AND FDDS

FIG. 2

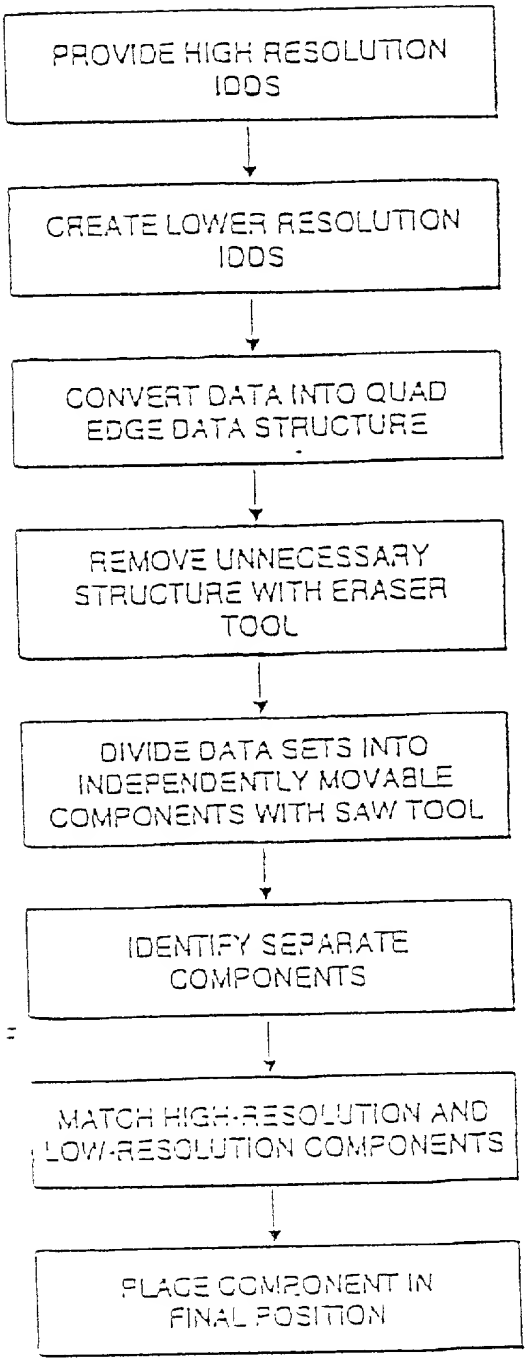

FIG. 3

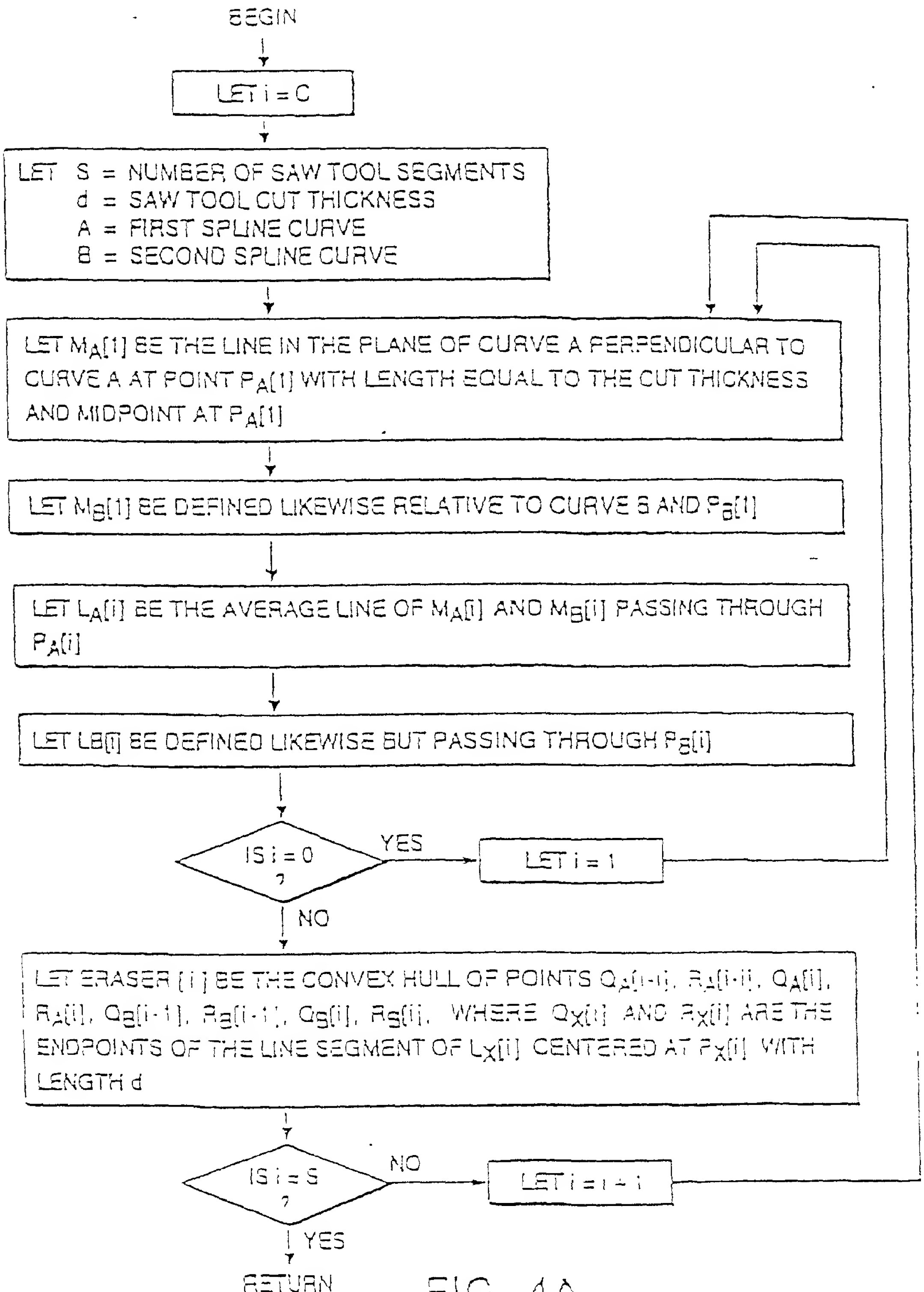
BEGIN
LET i = 0
LET S = NUMBER OF SAW TOOL SEGMENTS
d = SAW TOOL CUT THICKNESS
A = FIRST SPLINE CURVE
B = SECOND SPLINE CURVE
LET MA[1] BE THE LINE IN THE PLANE OF CURVE A PERPENDICULAR TO CURVE A AT POINT PA[1] WITH LENGTH EQUAL TO THE CUT THICKNESS AND MIDPOINT AT PA[1]
LET MB[1] BE DEFINED LIKEWISE RELATIVE TO CURVE B AND PB[1]
LET LA[i] BE THE AVERAGE LINE OF MA[i] AND MB[i] PASSING THROUGH PA[i]
LET LB[i] BE DEFINED LIKEWISE BUT PASSING THROUGH PB[i]
IS i = 0 ?
YES
LET i = 1
NO
LET ERASER [i] BE THE CONVEX HULL OF POINTS QA[i-1], RA[i-1], QA[i], RA[i], QB[i-1], RB[i-1], QB[i], RB[i], WHERE QX[i] AND RX[i] ARE THE ENDPOINTS OF THE LINE SEGMENT OF LX[i] CENTERED AT PX[i] WITH LENGTH d
IS i = S ?
NO
LET i = i + 1
YES
RETURN

FIG. 4A

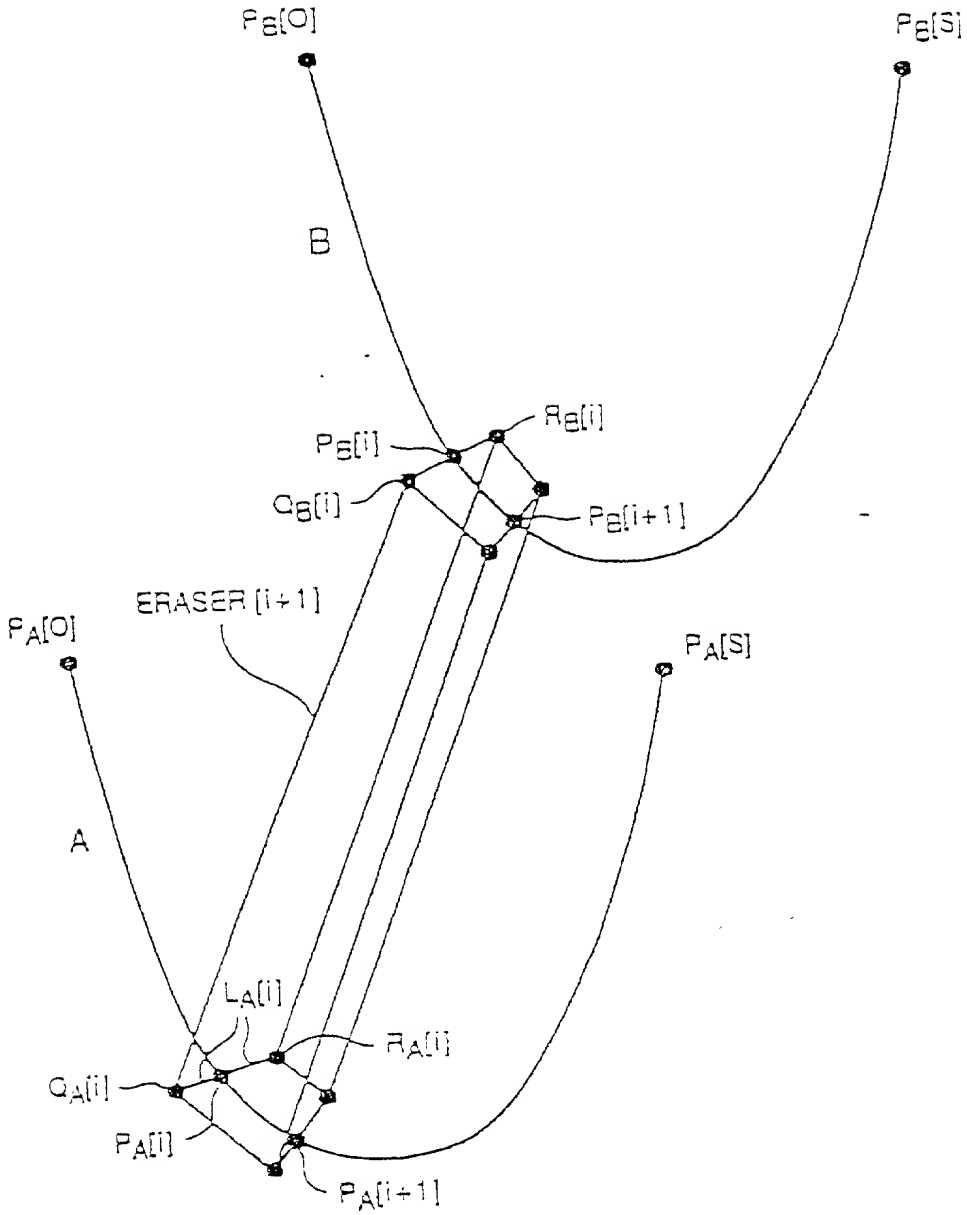
$P_B[O]$
$P_B[S]$
B
$R_B[i]$
$P_B[i]$
$Q_B[i]$
$P_B[i+1]$
ERASER [i+1]
$P_A[O]$
$P_A[S]$
A
$L_A[i]$
$R_A[i]$
$Q_A[i]$
$P_A[i]$
$P_A[i+1]$

FIG. 4B

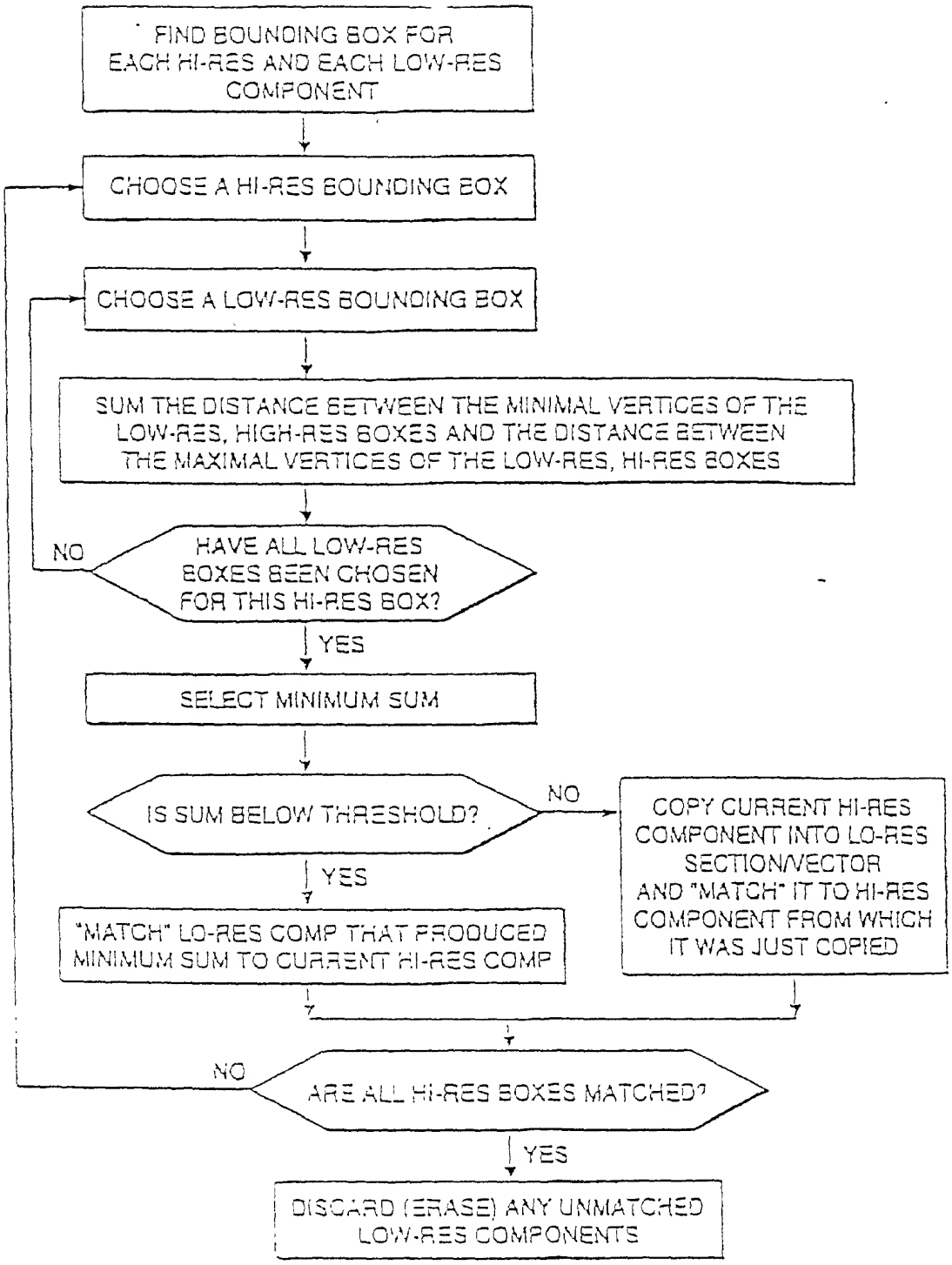
FIND BOUNDING BOX FOR EACH HI-RES AND EACH LOW-RES COMPONENT
CHOOSE A HI-RES BOUNDING BOX
CHOOSE A LOW-RES BOUNDING BOX
SUM THE DISTANCE BETWEEN THE MINIMAL VERTICES OF THE LOW-RES, HIGH-RES BOXES AND THE DISTANCE BETWEEN THE MAXIMAL VERTICES OF THE LOW-RES, HI-RES BOXES
NO
HAVE ALL LOW-RES BOXES BEEN CHOSEN FOR THIS HI-RES BOX?
YES
SELECT MINIMUM SUM
IS SUM BELOW THRESHOLD?
NO
COPY CURRENT HI-RES COMPONENT INTO LO-RES SECTION/VECTOR AND "MATCH" IT TO HI-RES COMPONENT FROM WHICH IT WAS JUST COPIED
YES
"MATCH" LO-RES COMP THAT PRODUCED MINIMUM SUM TO CURRENT HI-RES COMP
NO
ARE ALL HI-RES BOXES MATCHED?
YES
DISCARD (ERASE) ANY UNMATCHED LOW-RES COMPONENTS

FIG. 5

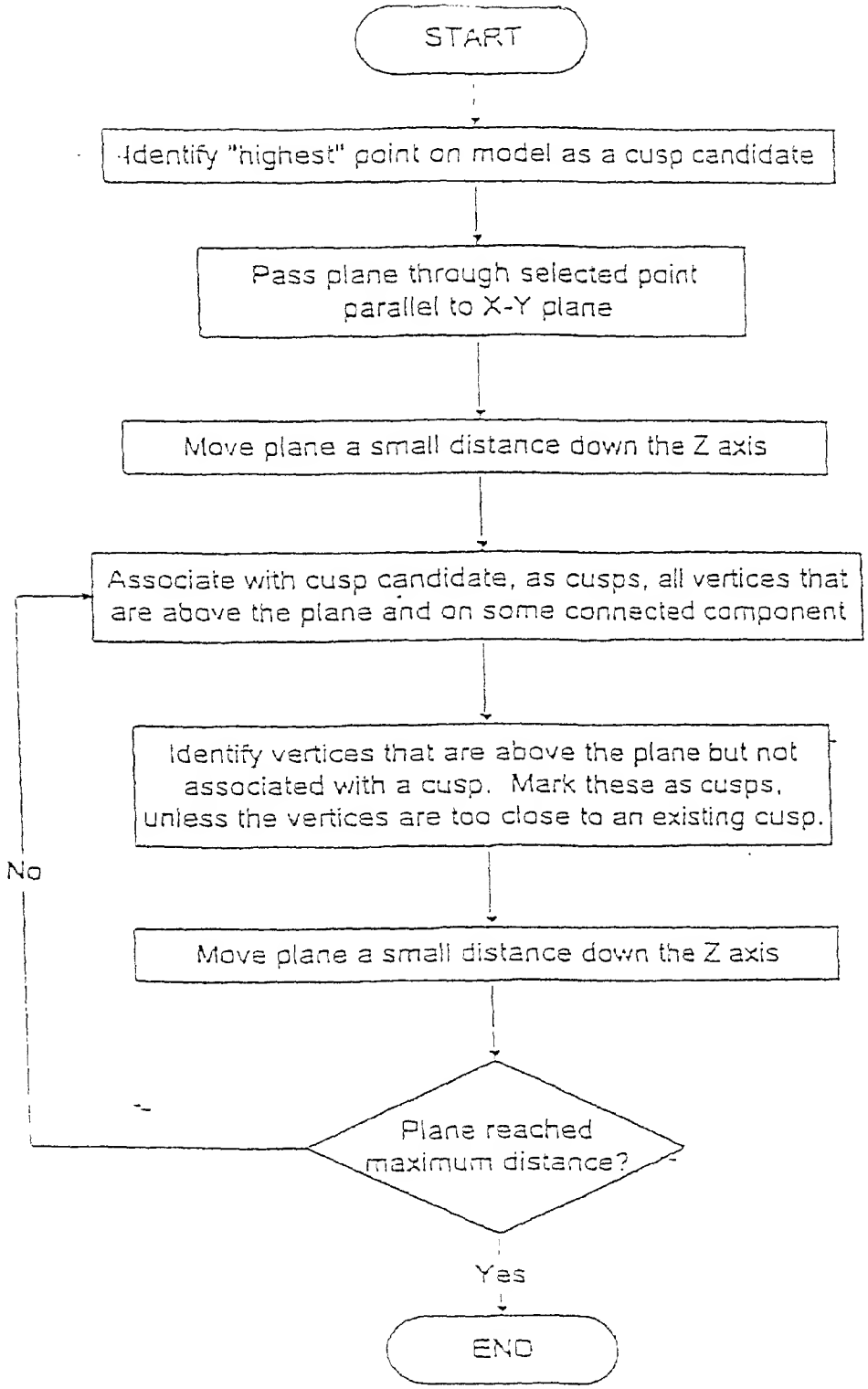
START
Identify "highest" point on model as a cusp candidate
Pass plane through selected point parallel to X-Y plane
Move plane a small distance down the Z axis
Associate with cusp candidate, as cusps, all vertices that are above the plane and on some connected component
Identify vertices that are above the plane but not associated with a cusp. Mark these as cusps, unless the vertices are too close to an existing cusp.
Move plane a small distance down the Z axis
Plane reached maximum distance?
No
Yes
END

FIG. 6A

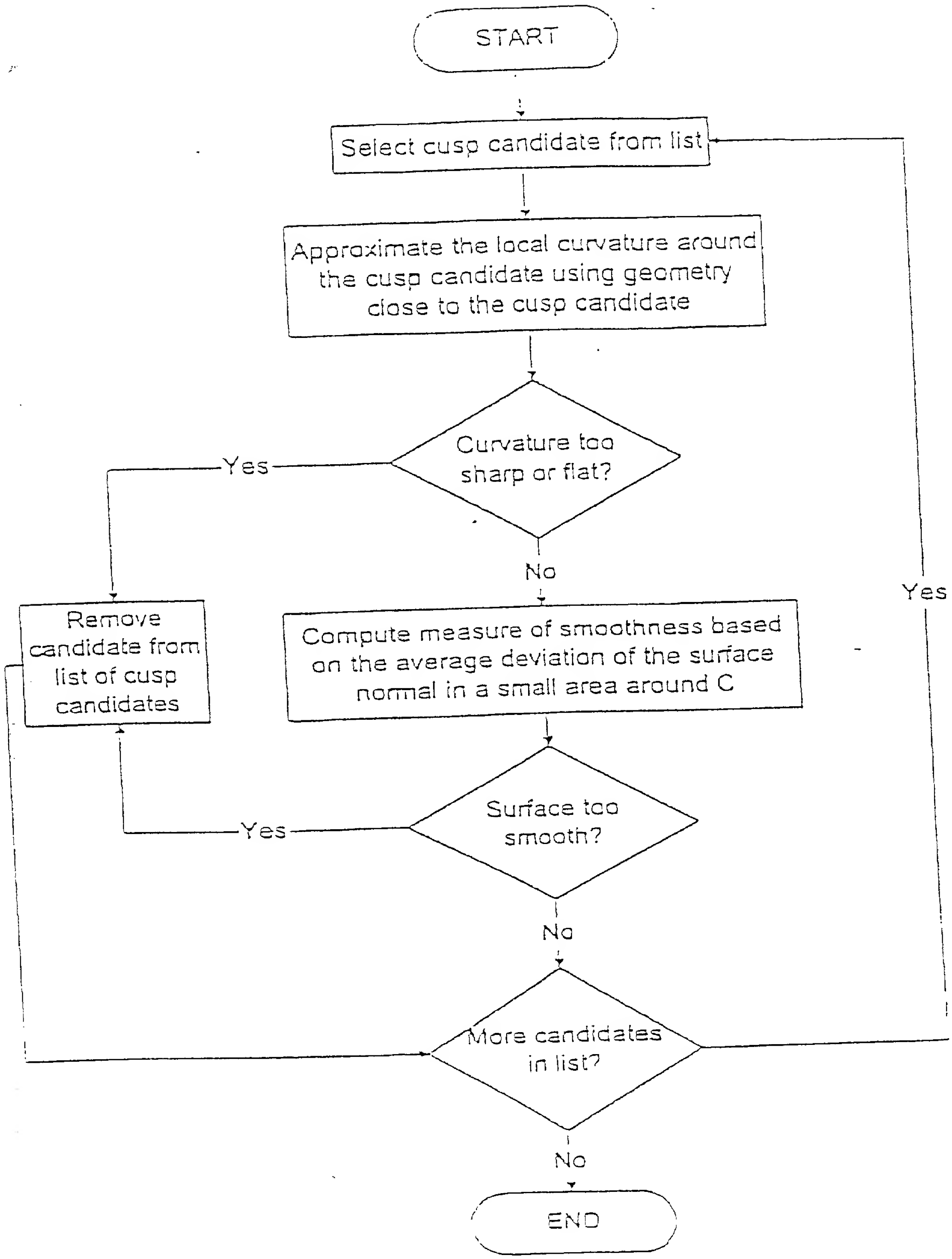
START
Select cusp candidate from list
Approximate the local curvature around the cusp candidate using geometry close to the cusp candidate
Curvature too sharp or flat?
Yes
No
Remove candidate from list of cusp candidates
Compute measure of smoothness based on the average deviation of the surface normal in a small area around C
Surface too smooth?
Yes
No
More candidates in list?
Yes
No
END

FIG. 6B

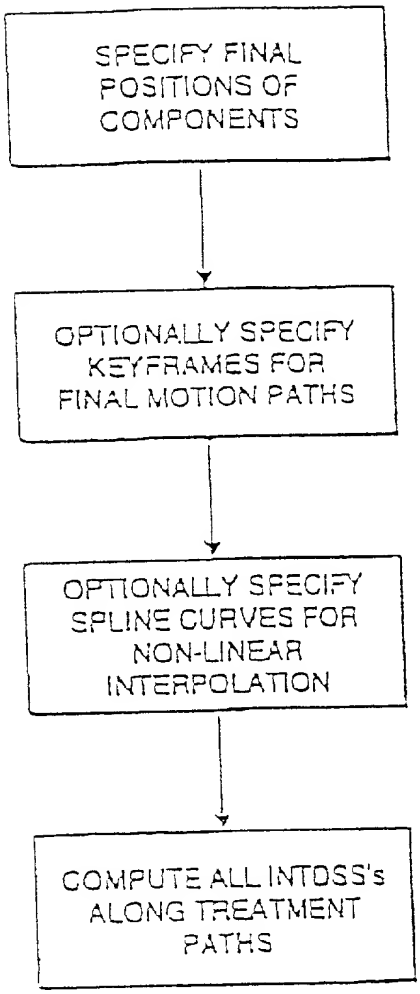
SPECIFY FINAL POSITIONS OF COMPONENTS
OPTIONALLY SPECIFY KEYFRAMES FOR FINAL MOTION PATHS
OPTIONALLY SPECIFY SPLINE CURVES FOR NON-LINEAR INTERPOLATION
COMPUTE ALL INTOSS's ALONG TREATMENT PATHS

FIG. 7

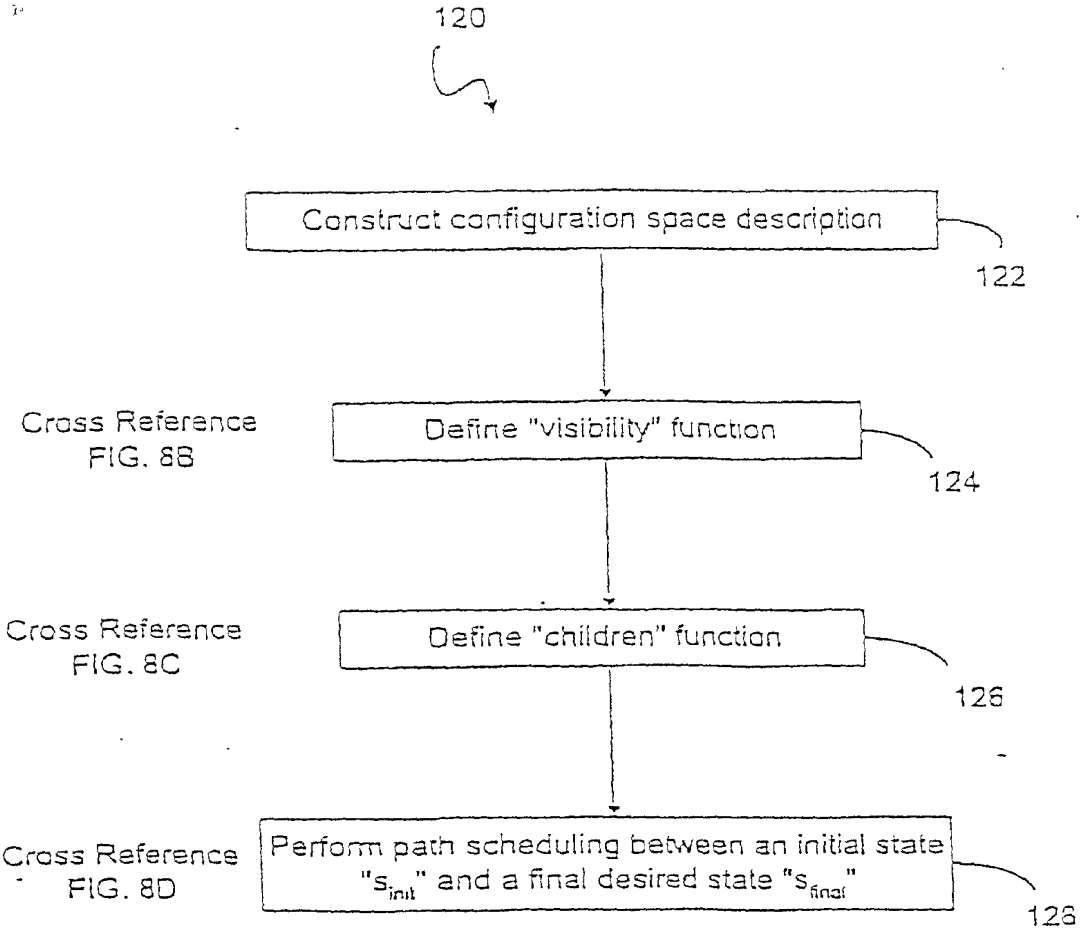

FIG. 8A

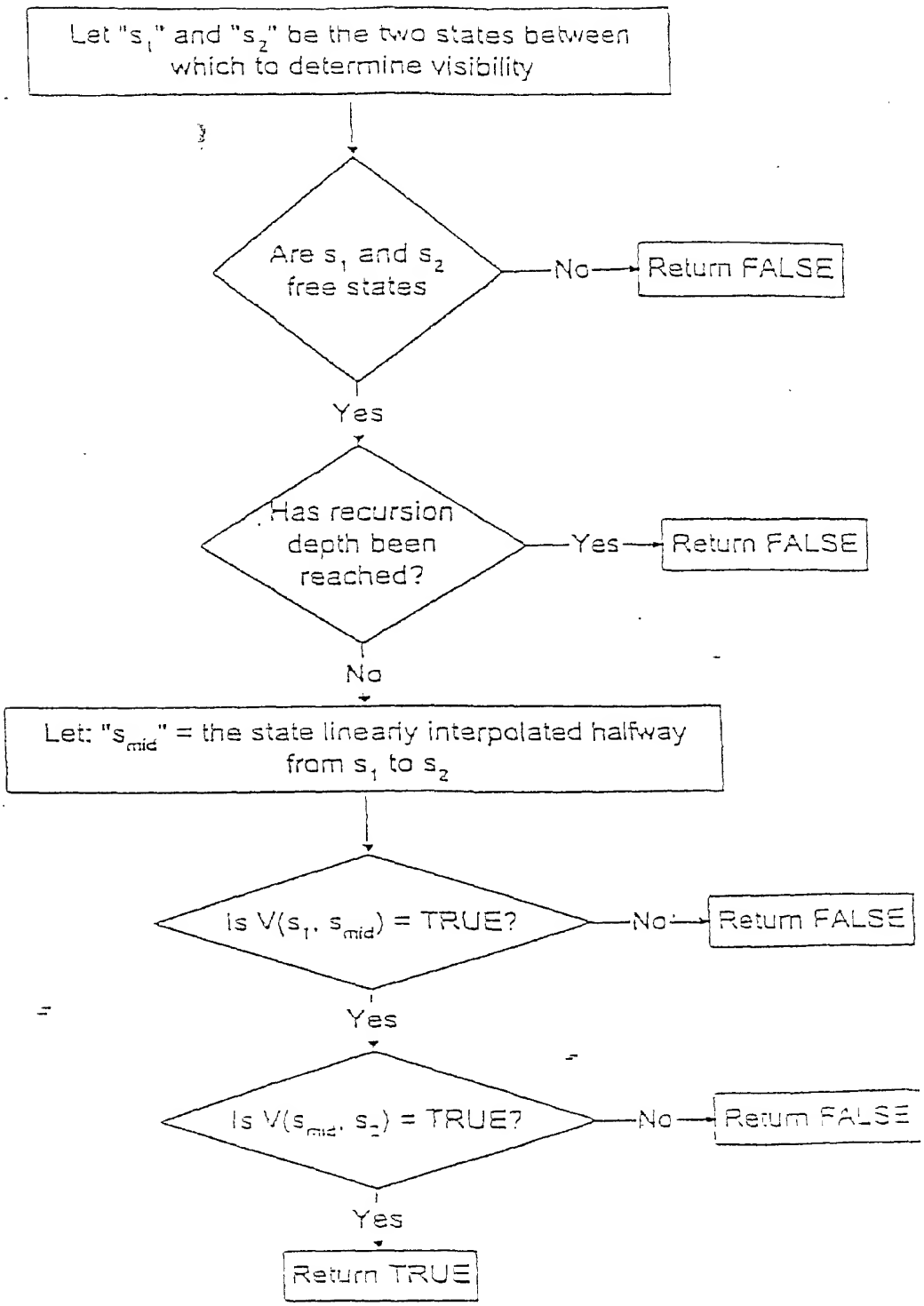
Let "s_1" and "s_2" be the two states between which to determine visibility
Are s_1 and s_2 free states
No
Return FALSE
Yes
Has recursion depth been reached?
Yes
Return FALSE
No
Let: "s_{mid}" = the state linearly interpolated halfway from s_1 to s_2
Is $V(s_1, s_{mid})$ = TRUE?
No
Return FALSE
Yes
Is $V(s_{mid}, s_2)$ = TRUE?
No
Return FALSE
Yes
Return TRUE

FIG. 8B

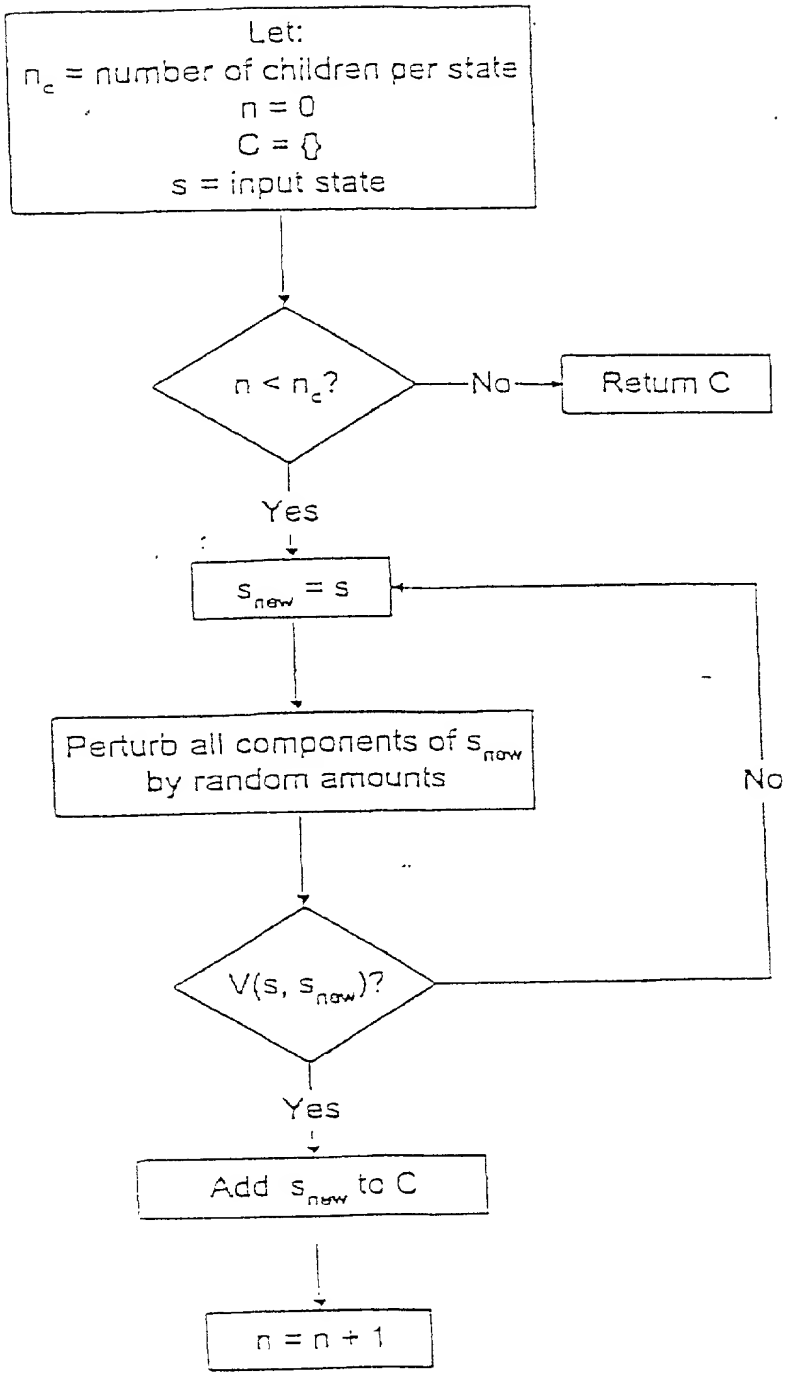
Let:
n_c = number of children per state
n = 0
C = {}
s = input state
$n < n_c$?
No
Return C
Yes
$s_{new} = s$
Perturb all components of s_{new} by random amounts
No
$V(s, s_{new})$?
Yes
Add s_{new} to C
n = n + 1

FIG. 8C

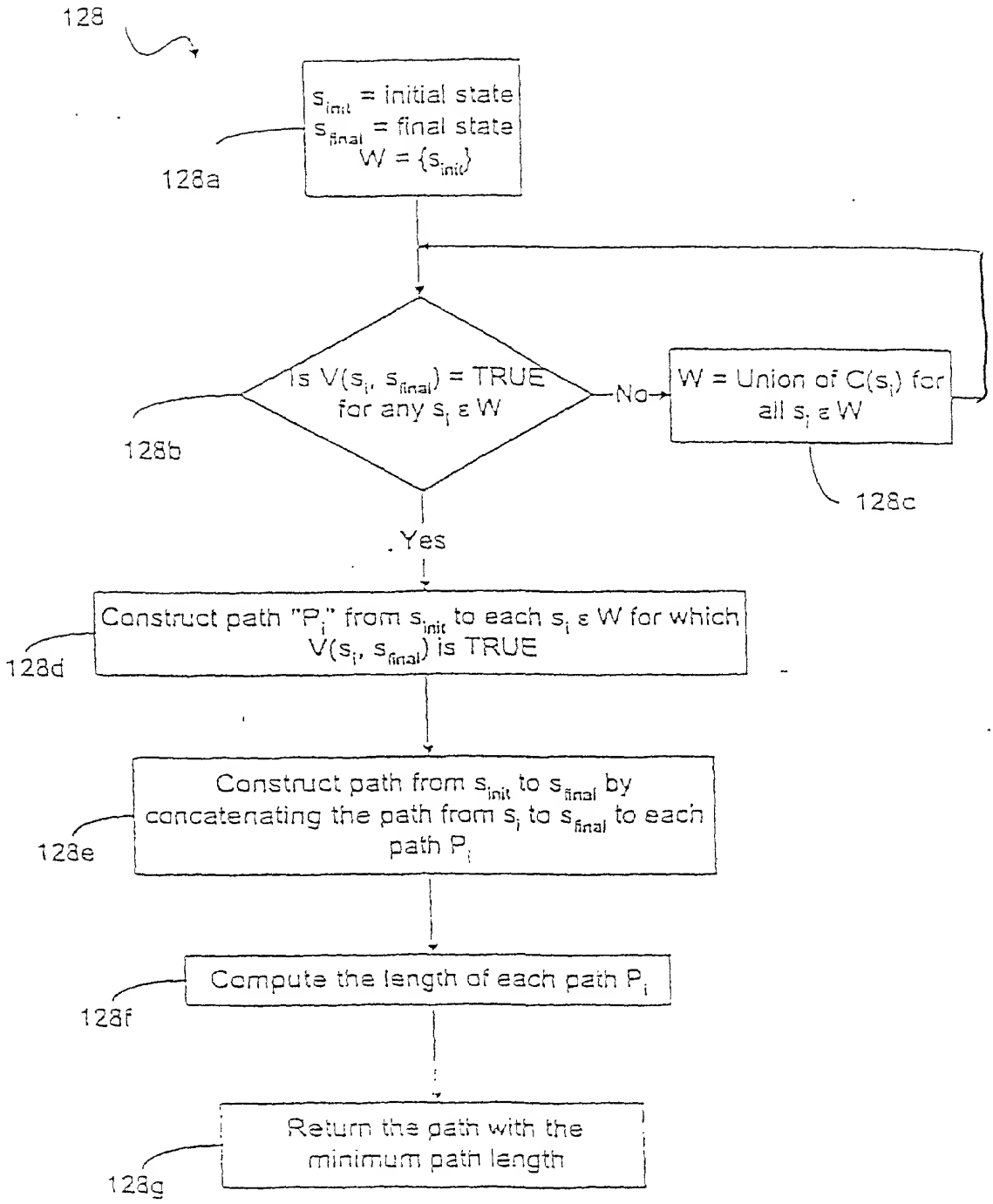
128
s_{init} = initial state
s_{final} = final state
$W = \{s_{init}\}$
128a
Is $V(s_i, s_{final})$ = TRUE for any $s_i \varepsilon W$
No
W = Union of $C(s_i)$ for all $s_i \varepsilon W$
128b
128c
Yes
Construct path "P_i" from s_{init} to each $s_i \varepsilon W$ for which $V(s_i, s_{final})$ is TRUE
128d
Construct path from s_{init} to s_{final} by concatenating the path from s_i to s_{final} to each path P_i
128e
Compute the length of each path P_i
128f
Return the path with the minimum path length
128g

FIG. 8D

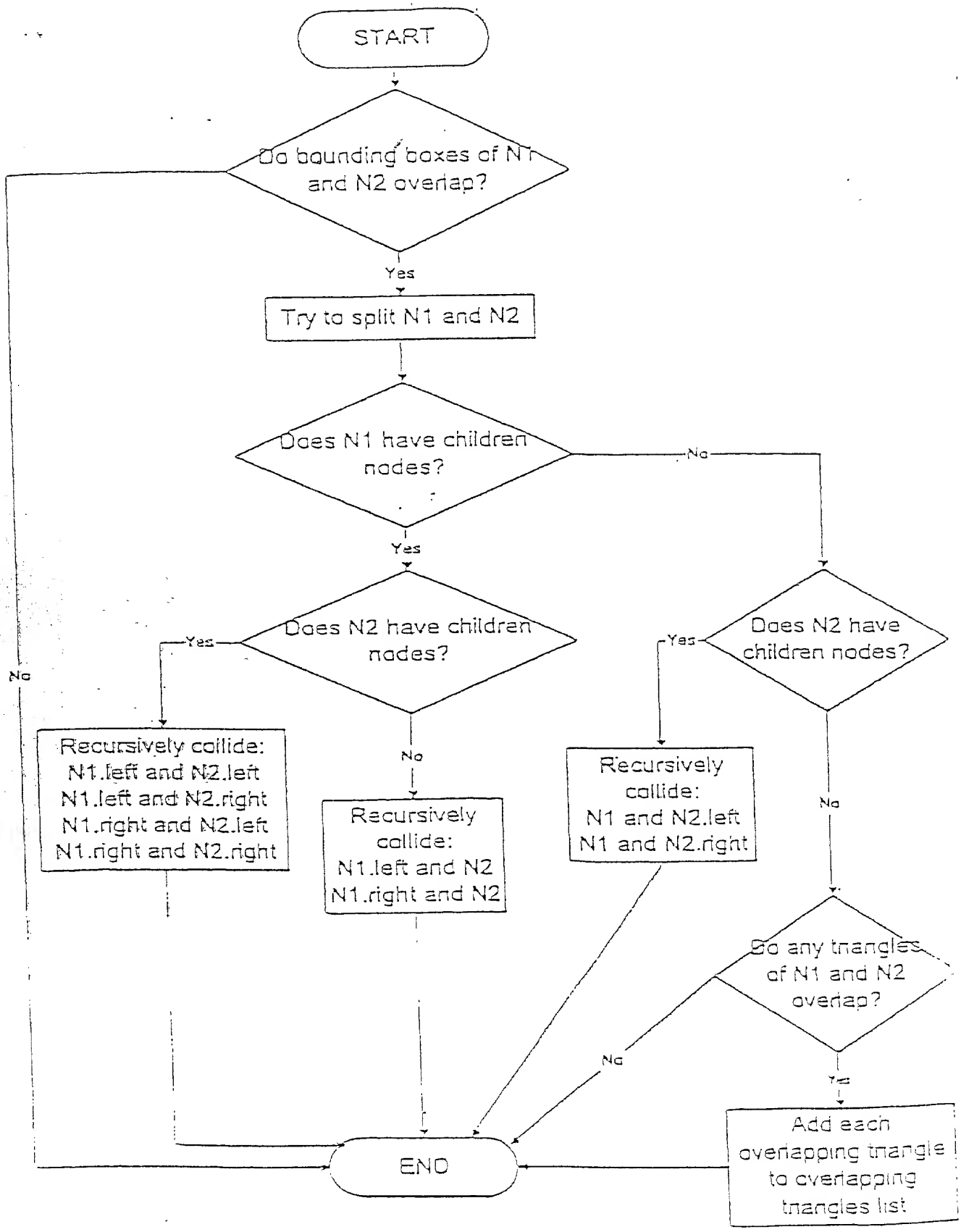
START
Do bounding boxes of N1 and N2 overlap?
Yes
No
Try to split N1 and N2
Does N1 have children nodes?
Yes
No
Does N2 have children nodes?
Yes
No
Recursively collide:
N1.left and N2.left
N1.left and N2.right
N1.right and N2.left
N1.right and N2.right
Recursively collide:
N1.left and N2
N1.right and N2
Does N2 have children nodes?
Yes
No
Recursively collide:
N1 and N2.left
N1 and N2.right
Do any triangles of N1 and N2 overlap?
No
Yes
Add each overlapping triangle to overlapping triangles list
END

FIG. 9A

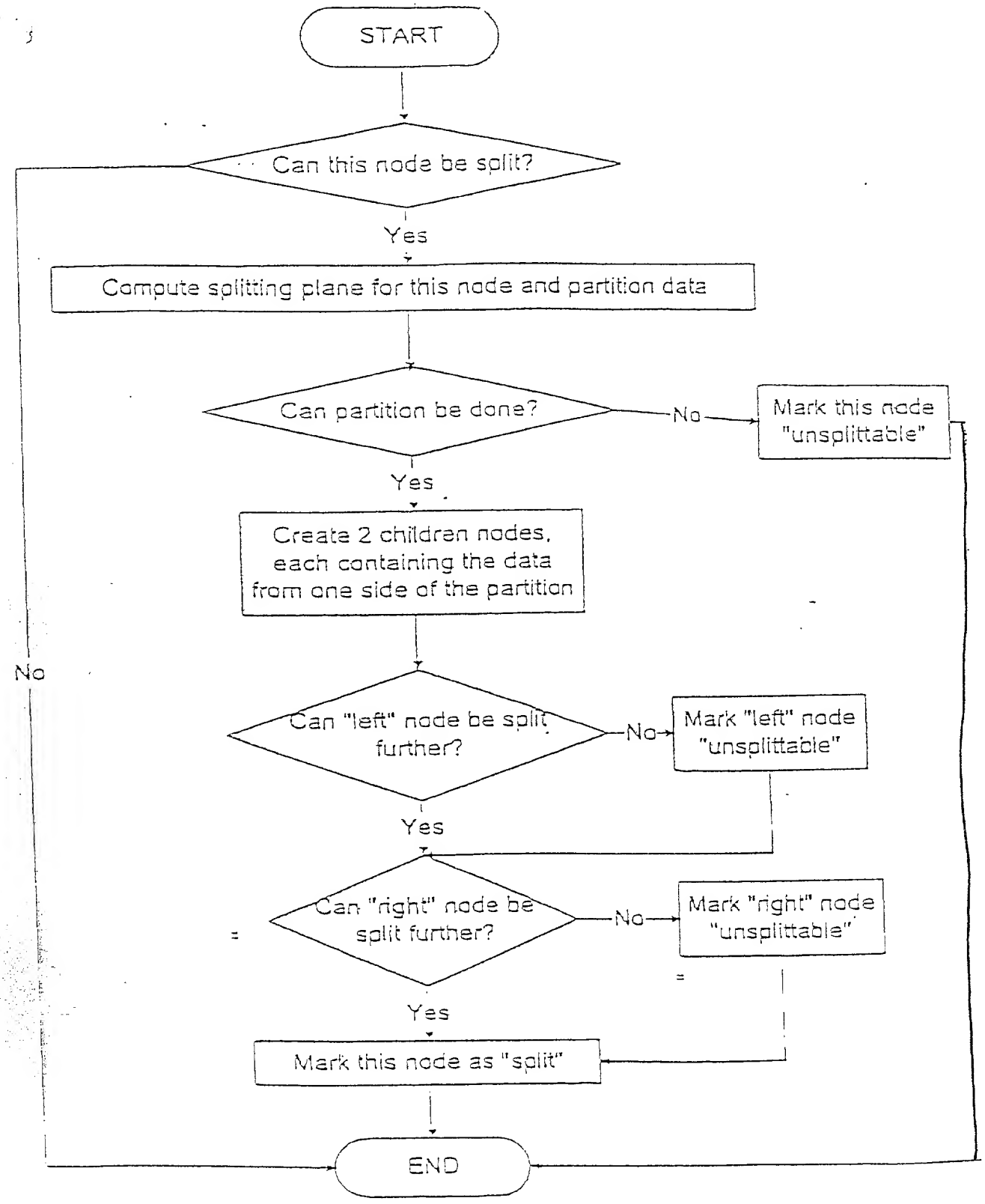

FIG. 9B

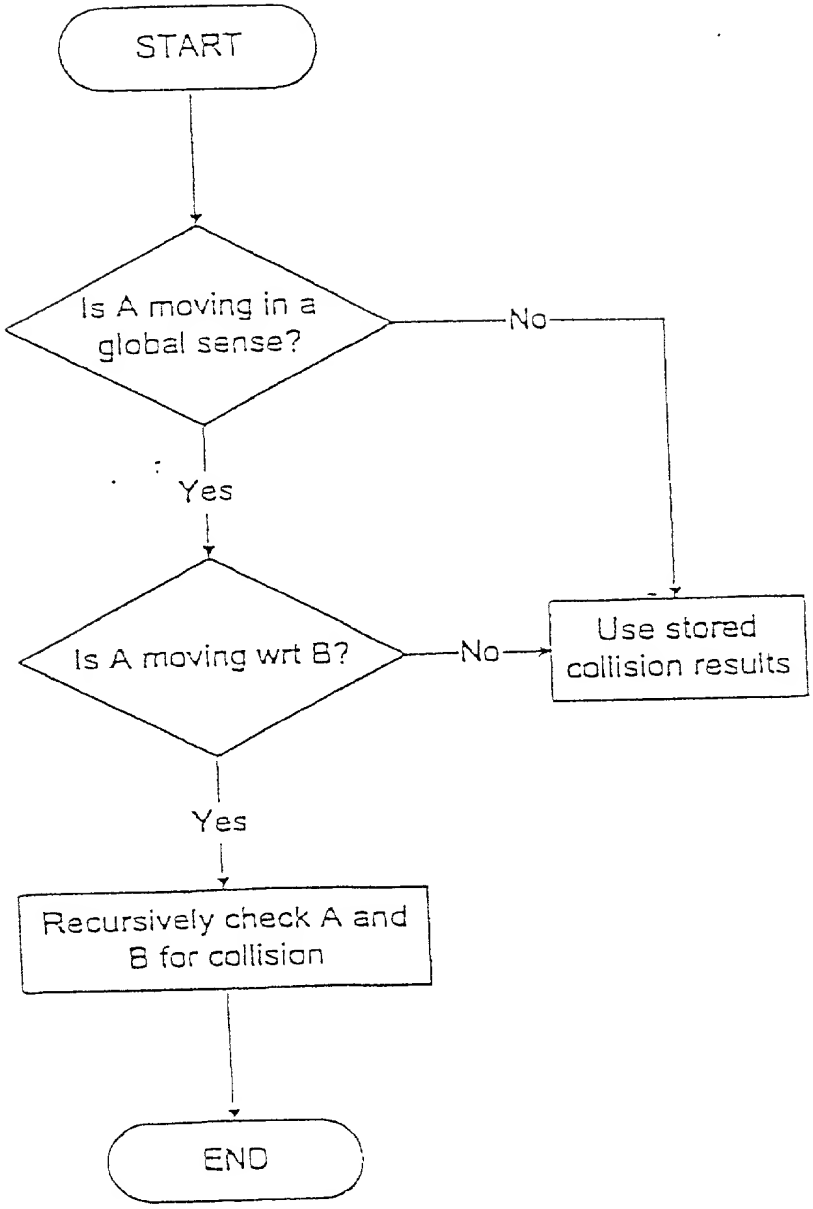
START
Is A moving in a global sense?
No
Yes
Is A moving wrt B?
No
Use stored collision results
Yes
Recursively check A and B for collision
END

FIG. 9C

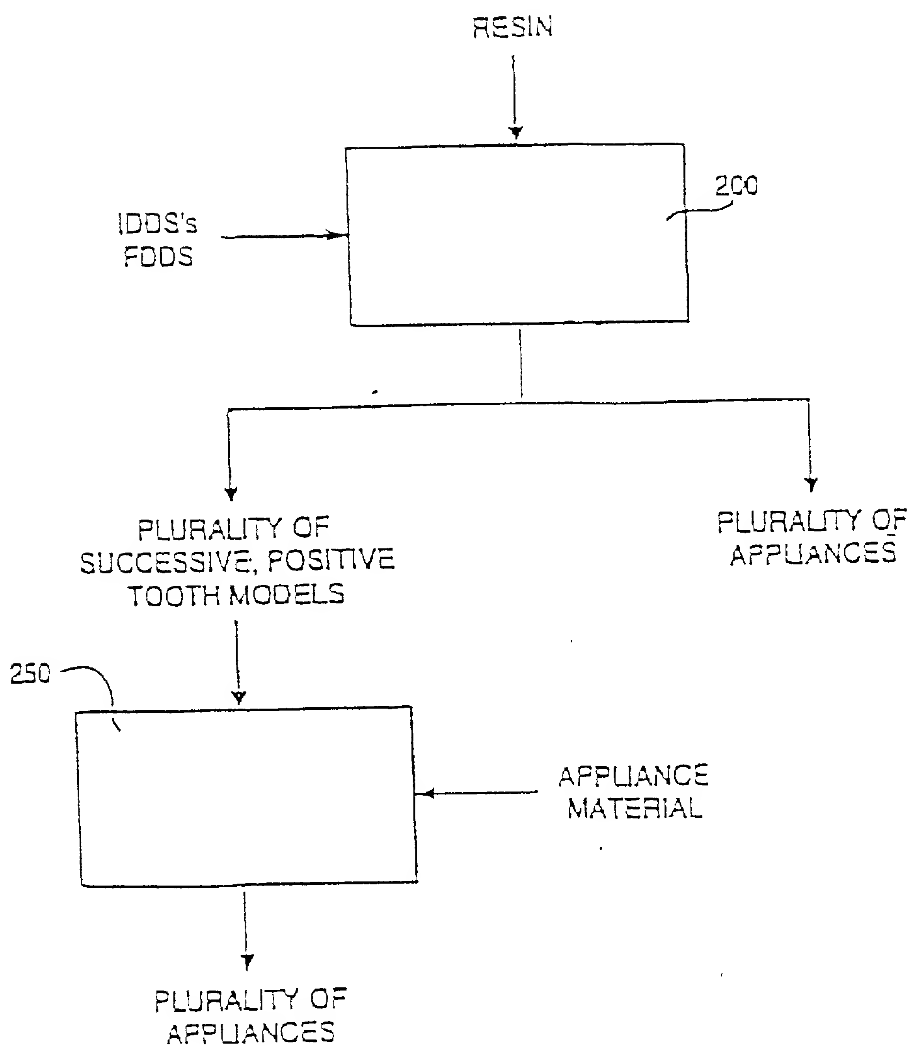
RESIN
200
IDDS's
FDDS
PLURALITY OF
SUCCESSIVE, POSITIVE
TOOTH MODELS
PLURALITY OF
APPLIANCES
250
APPLIANCE
MATERIAL
PLURALITY OF
APPLIANCES

FIG. 10

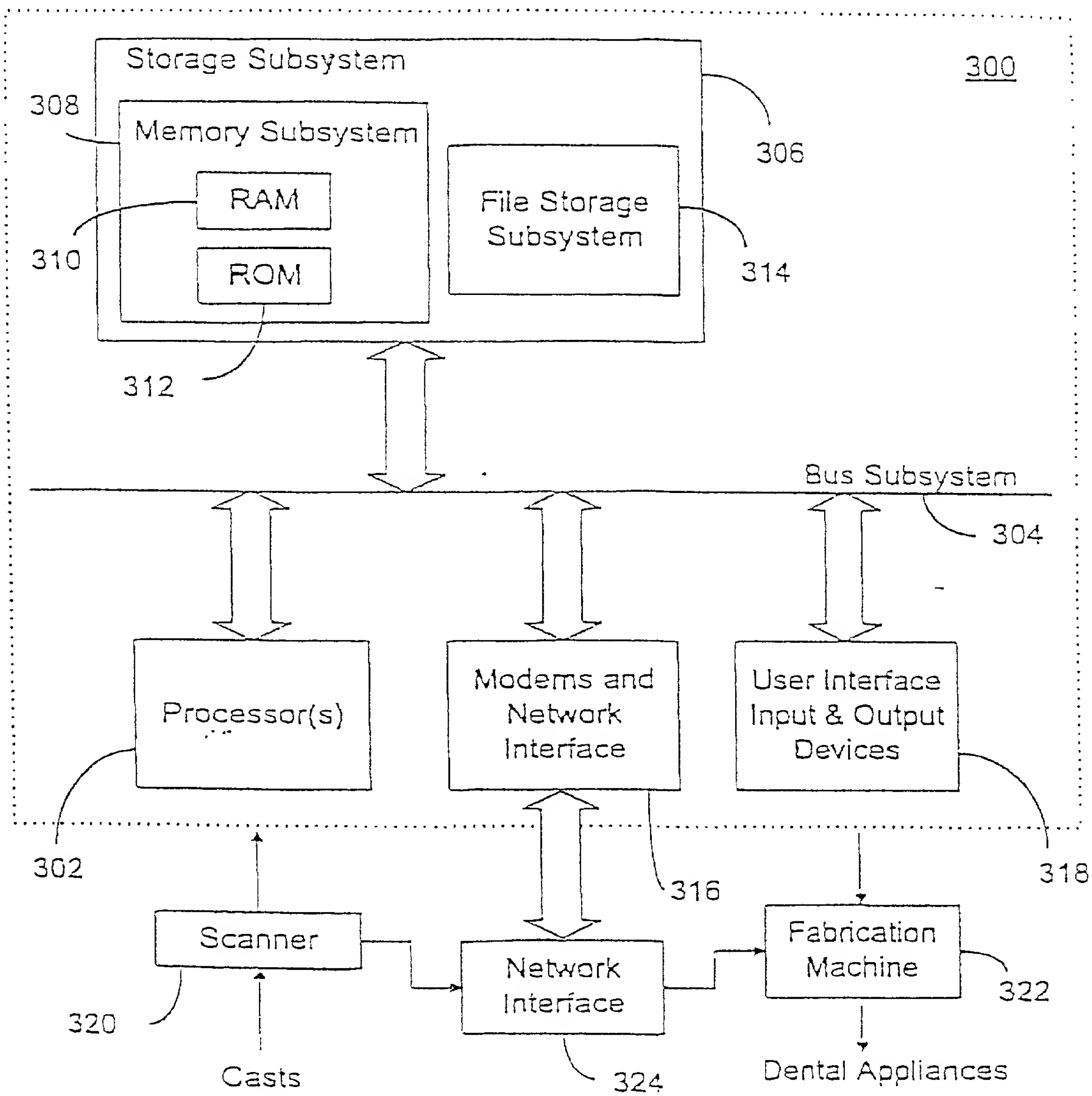

FIG. 11

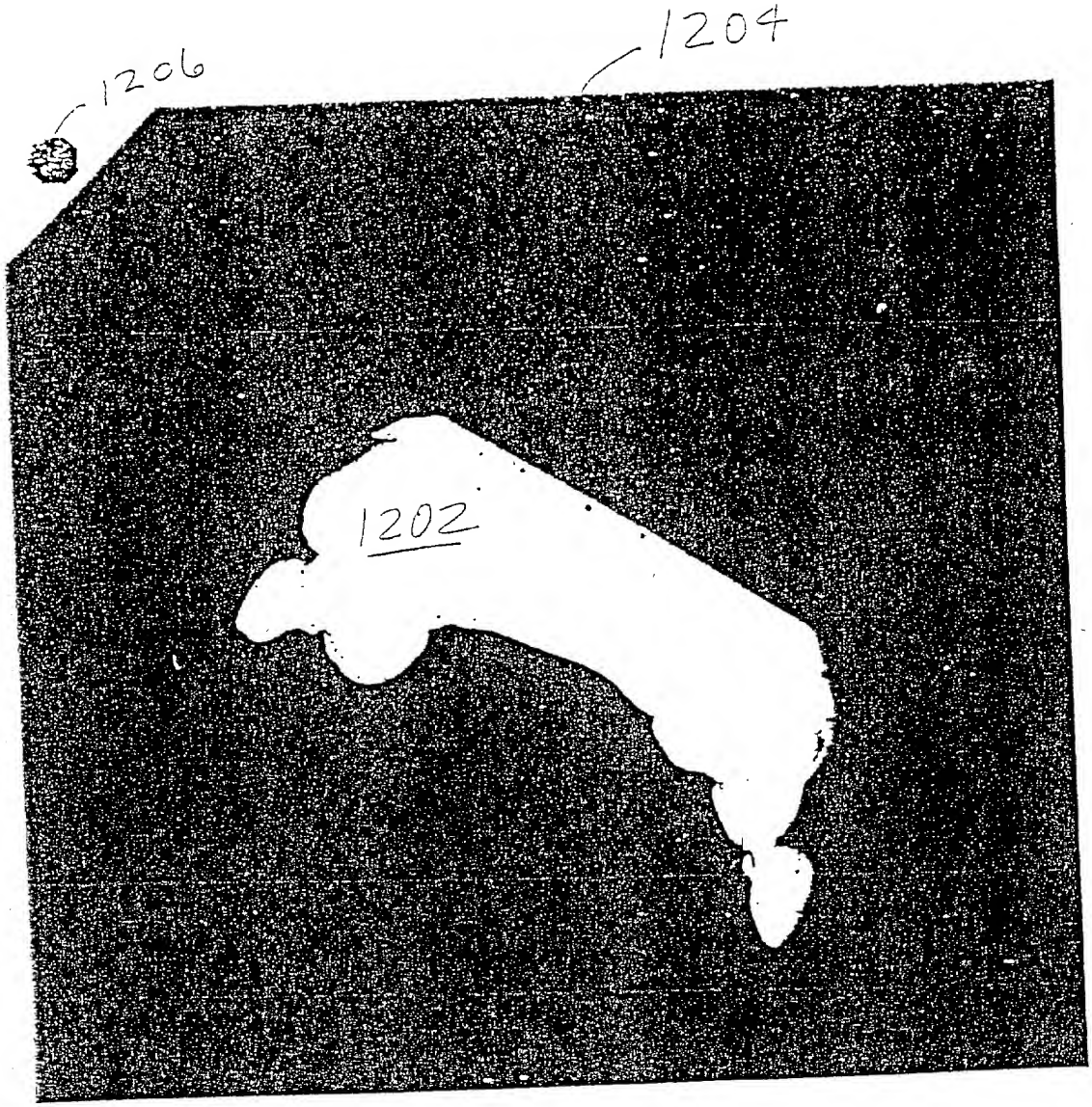

FIG. 12

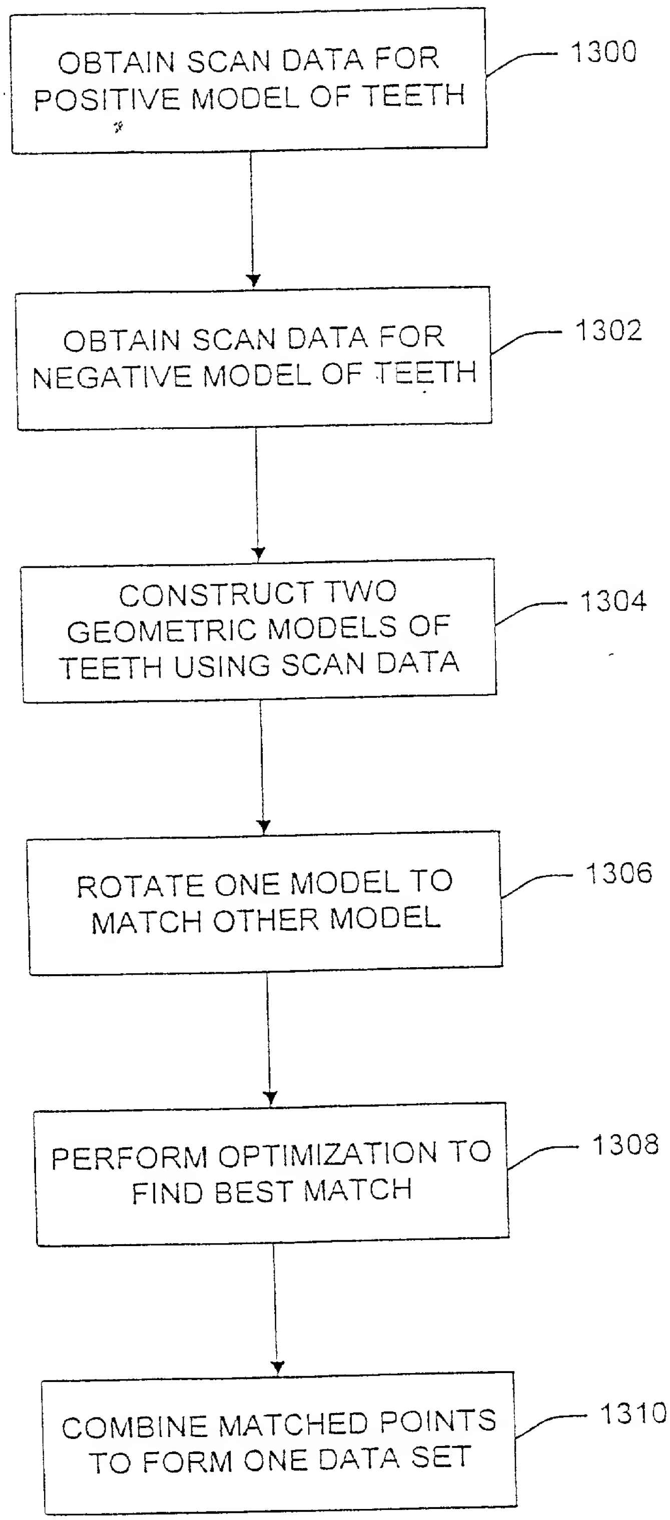

FIG. 13

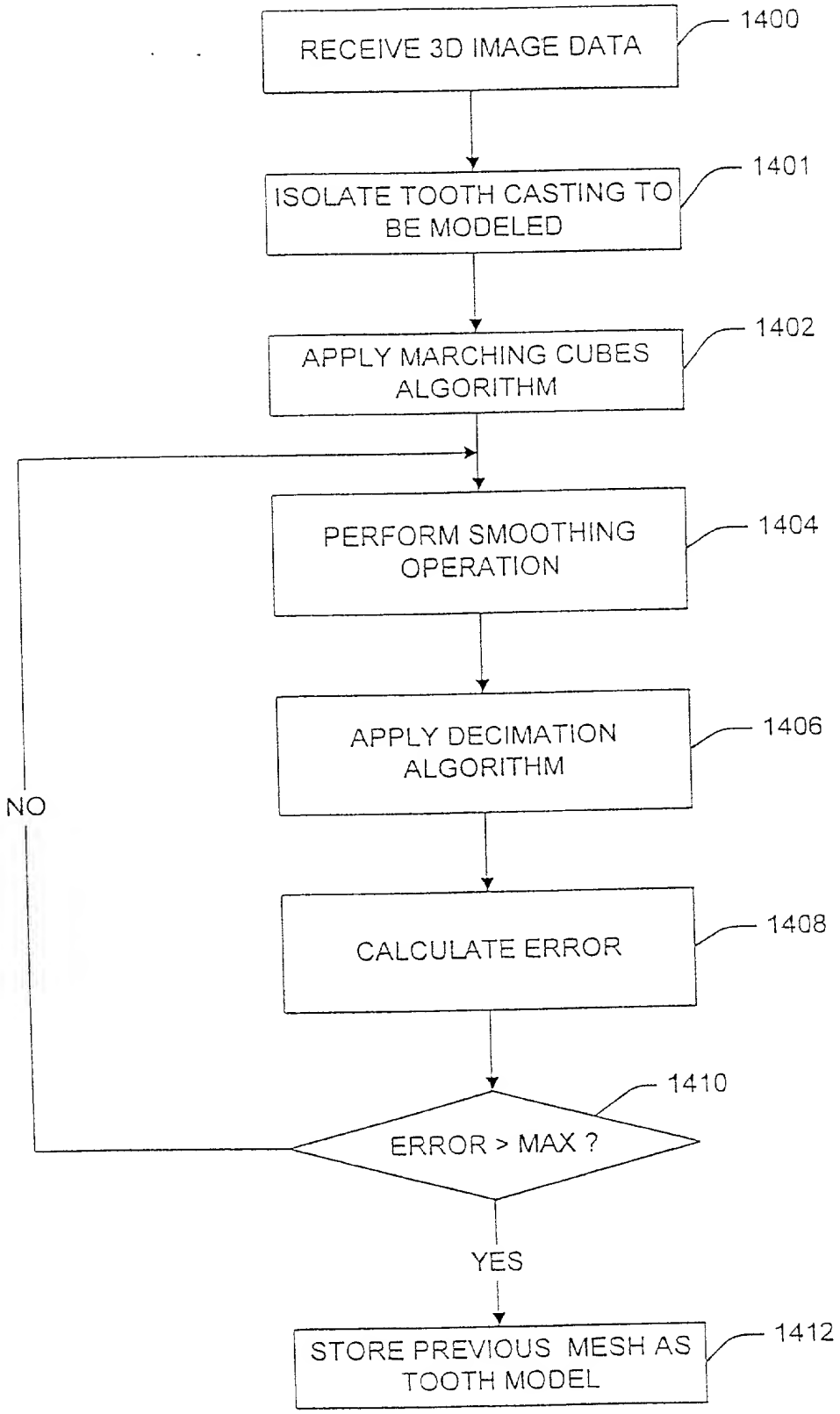
RECEIVE 3D IMAGE DATA
1400
ISOLATE TOOTH CASTING TO BE MODELED
1401
APPLY MARCHING CUBES ALGORITHM
1402
PERFORM SMOOTHING OPERATION
1404
APPLY DECIMATION ALGORITHM
1406
CALCULATE ERROR
1408
ERROR > MAX ?
1410
NO
YES
STORE PREVIOUS MESH AS TOOTH MODEL
1412

FIG. 14

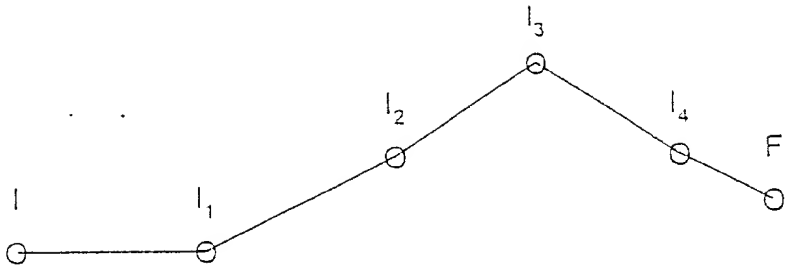

FIG. 15A

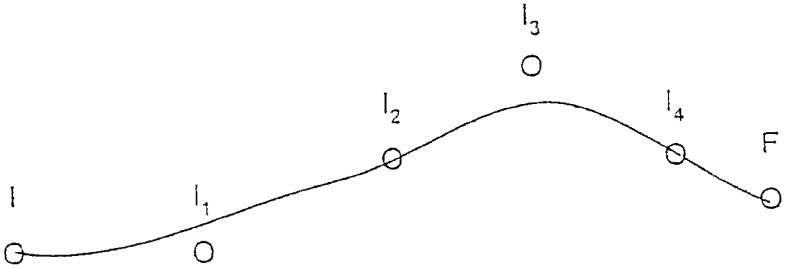

FIG. 15B

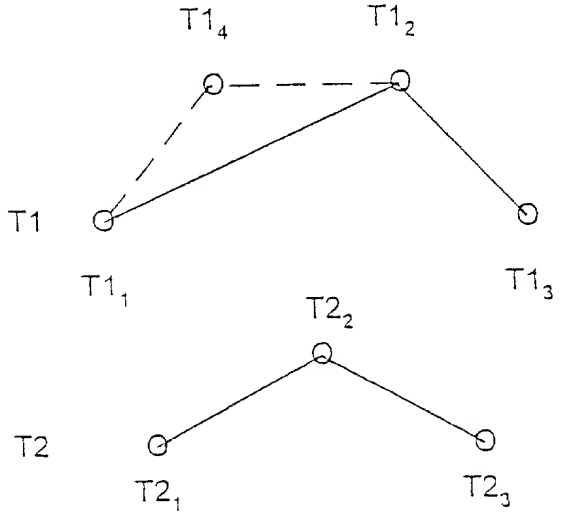

FIG. 15C

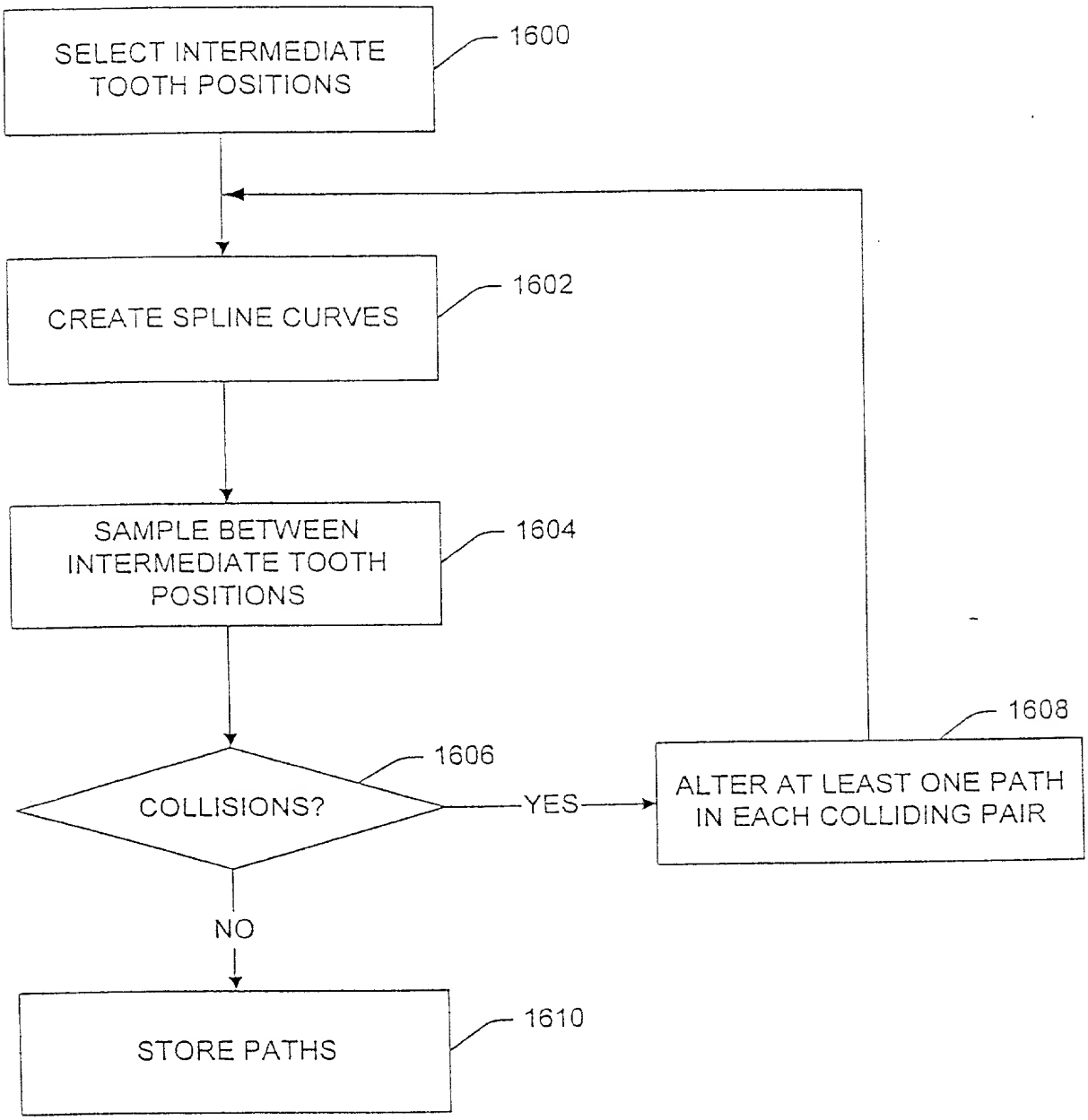
SELECT INTERMEDIATE TOOTH POSITIONS
1600
CREATE SPLINE CURVES
1602
SAMPLE BETWEEN INTERMEDIATE TOOTH POSITIONS
1604
COLLISIONS?
1606
YES
ALTER AT LEAST ONE PATH IN EACH COLLIDING PAIR
1608
NO
STORE PATHS
1610

FIG. 16

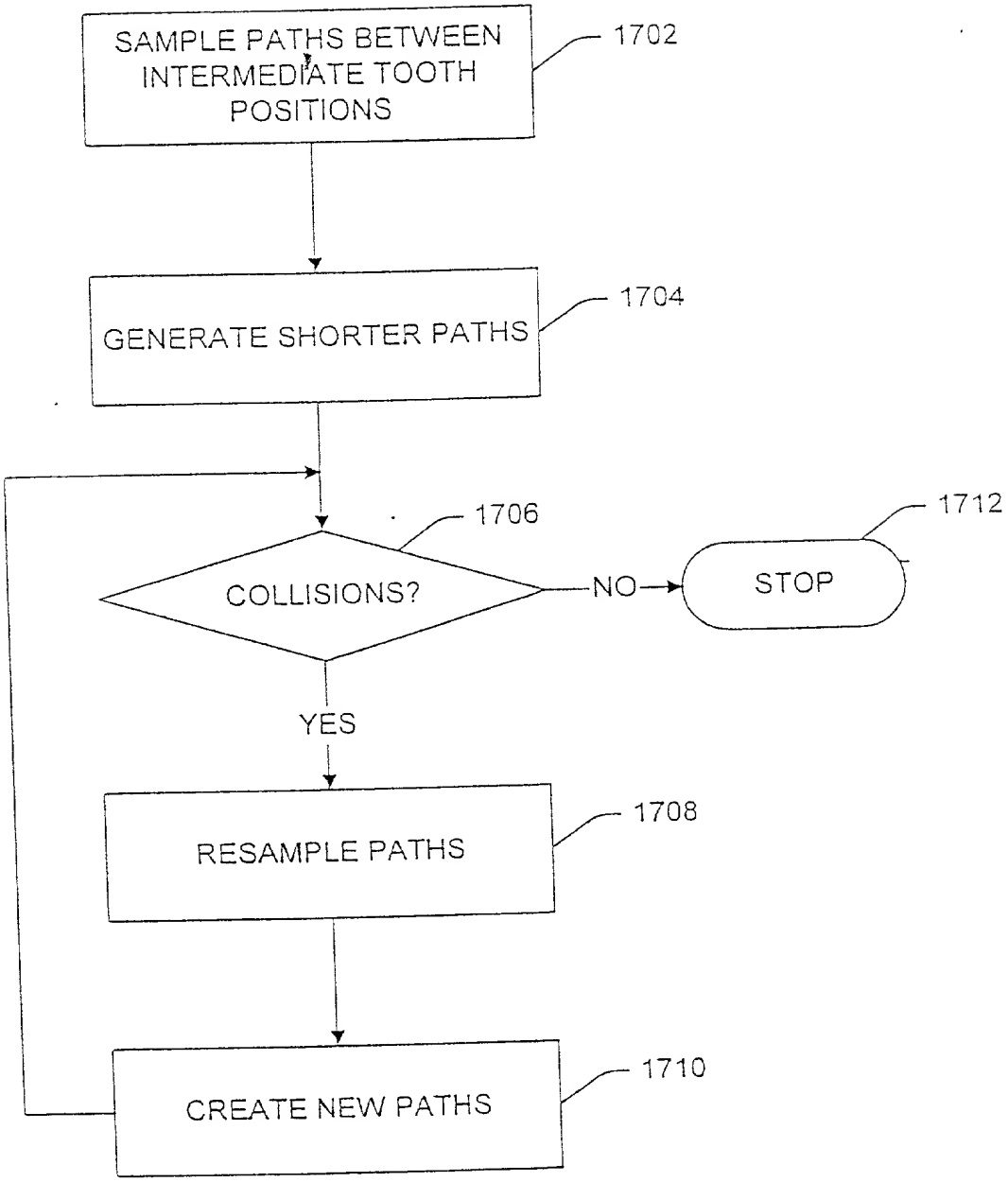
SAMPLE PATHS BETWEEN INTERMEDIATE TOOTH POSITIONS
1702
GENERATE SHORTER PATHS
1704
1706
COLLISIONS?
NO
STOP
1712
YES
RESAMPLE PATHS
1708
CREATE NEW PATHS
1710

FIG. 17

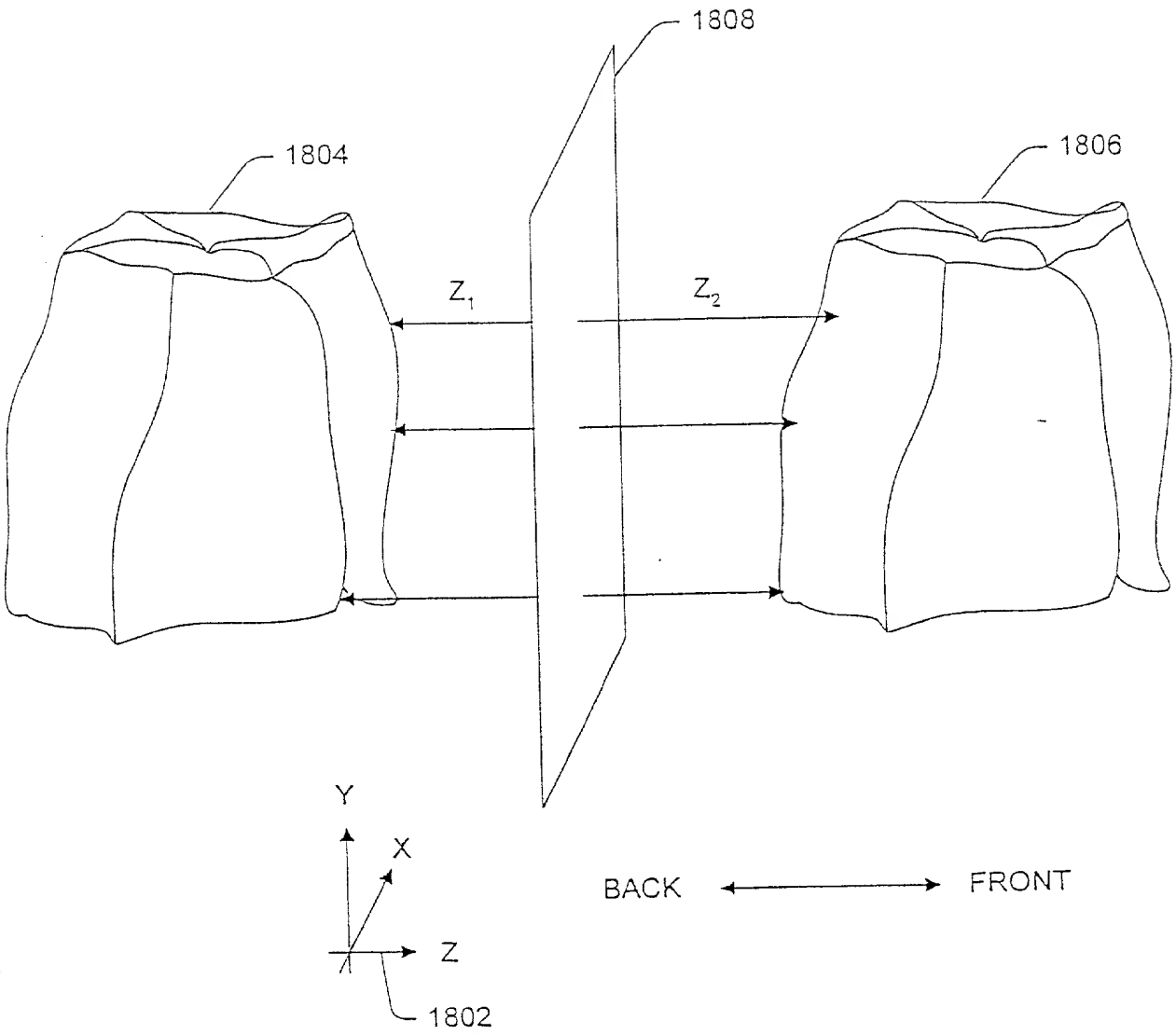

FIG. 18

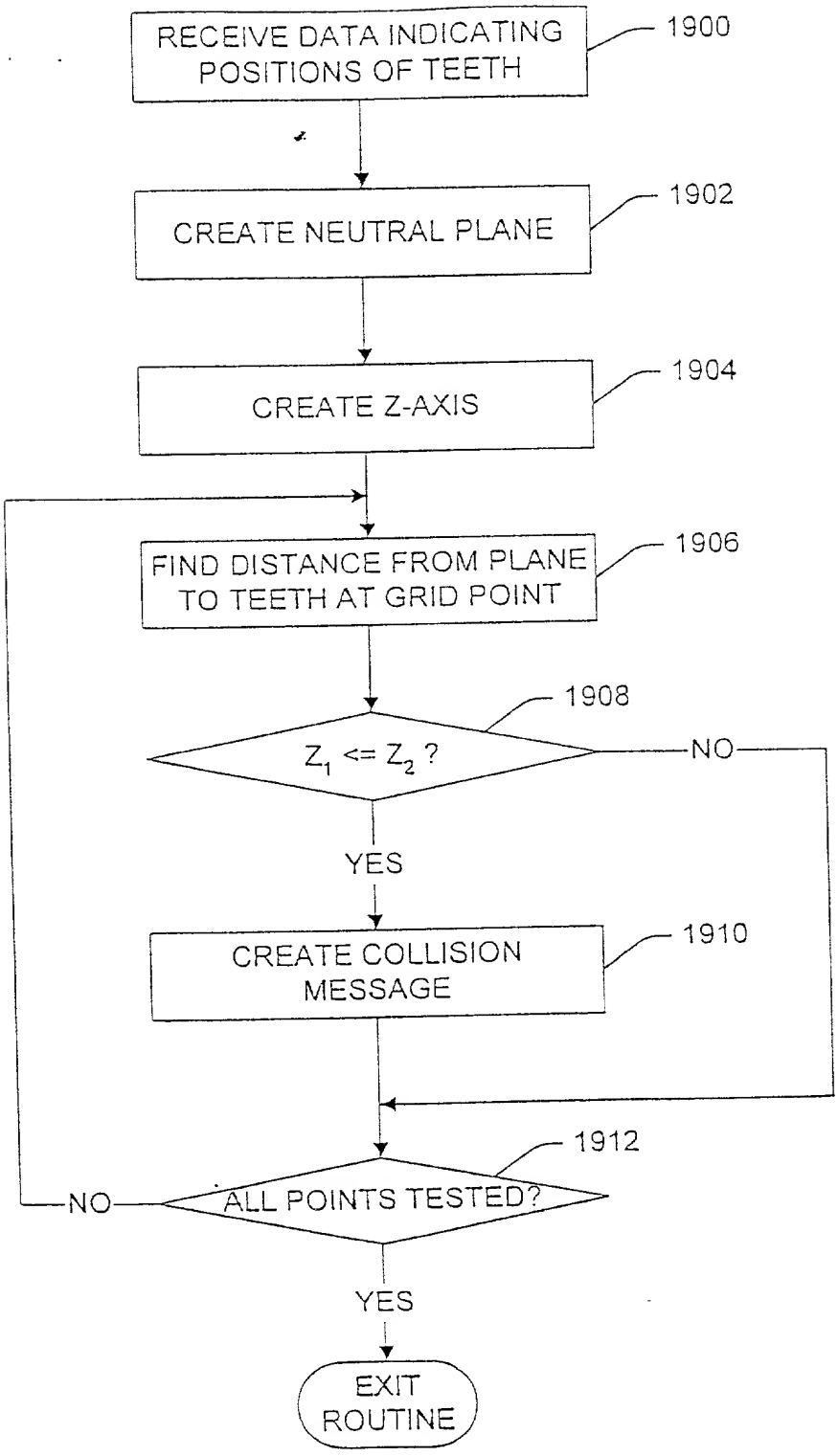
RECEIVE DATA INDICATING POSITIONS OF TEETH
1900
CREATE NEUTRAL PLANE
1902
CREATE Z-AXIS
1904
FIND DISTANCE FROM PLANE TO TEETH AT GRID POINT
1906
$Z_1 <= Z_2$?
1908
NO
YES
CREATE COLLISION MESSAGE
1910
ALL POINTS TESTED?
1912
NO
YES
EXIT ROUTINE

FIG. 19

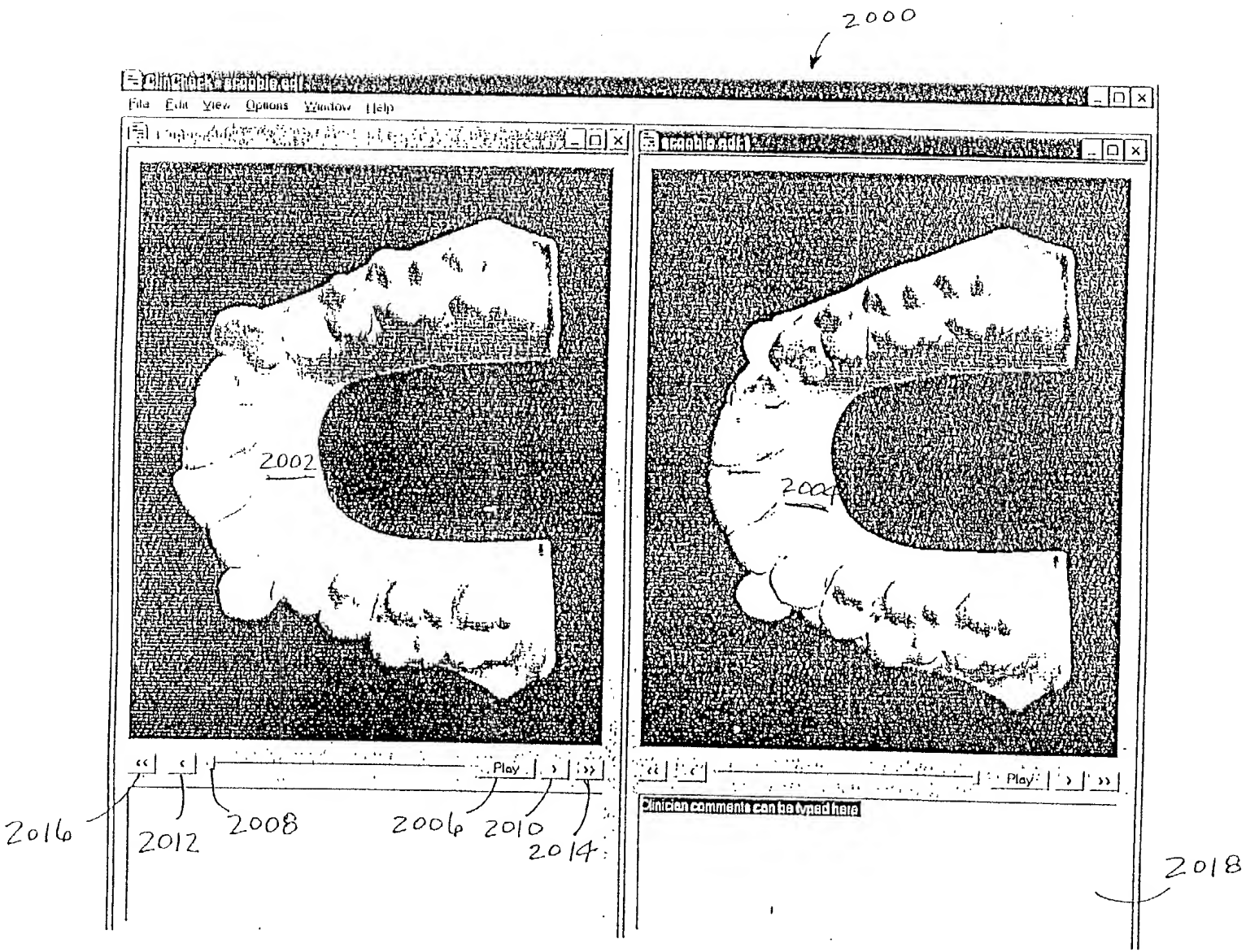

FIG. 20

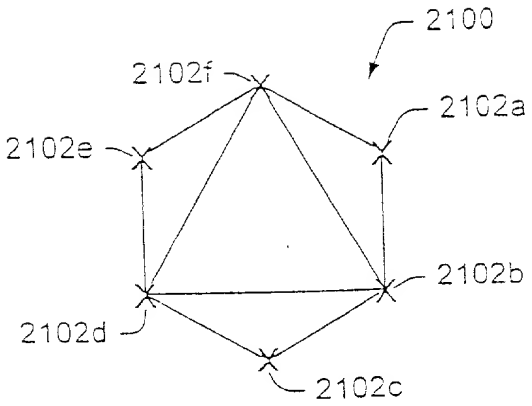

FIG. 21A

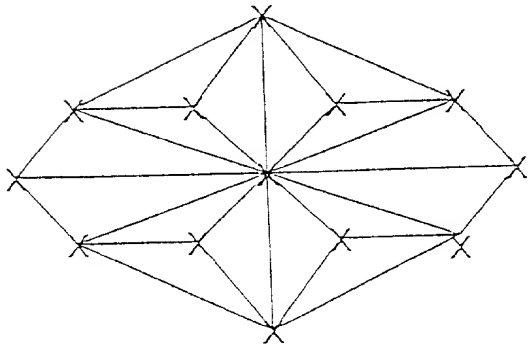

FIG. 21B